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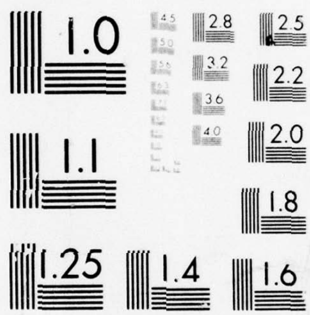

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This study attempts to determine if there is a need for a helicopter aeromedical research capability. The need for helicopter aeromedical research is examined from several aspects: (1) a historical review of aeromedical research from the beginning of flight up to the establishment of a helicopter aeromedical research laboratory in 1962; (2) the correlation of physiological problems associated with each new development in airplane technology; (3) an analysis of the Army, Navy, and Air Force aeromedical research facilities, capabilities, and programs; (4) a comparative analysis of the three military departments resources; and (5) review of the threat facing ground forces today.

Major conclusions of the study reveal an imperative need for a dedicated helicopter aeromedical research capability and indicates that present facilities and funds are inadequate. Review of the threat faced by the United States ground forces in Europe reinforces the need for a dedicated helicopter aeromedical research facility to support the Army's expanded use of helicopters in a high intensity conflict. New helicopters produce new physiological problems which must be solved for man to operate helicopters safely and effectively. The need for helicopter aeromedical research continues longitudinally with the development of increasingly complex and sophisticated helicopters.

HELICOPTER AEROMEDICAL RESEARCH: THE NEED

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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B.S., Troy State University, 1963
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Helicopter Aeromedical Research: The Need

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Final report 10 June 1977

A Master of Military Art and Science thesis presented to the faculty of the U.S. Army Command and General Staff College, Fort Leavenworth, Kansas 66027

ABSTRACT

The need for helicopter aeromedical research is examined from several aspects: (1) a historical review of aeromedical research from the beginning of flight to the establishment of an Army helicopter aeromedical research laboratory in 1962; (2) the correlation of physiological problems associated with each new development in airplane technology; (3) an analysis of the Army, Navy, and Air Force aeromedical research facilities, capabilities, and programs; (4) a comparative analysis of the three military department's aircraft resources; and (5) a review of the threat facing Army ground forces today.

The study reveals an imperative need for a dedicated helicopter aeromedical research capability and indicates that present facilities and funds are inadequate. An analysis of the three military department's research facilities, capabilities, and programs indicate a duplication of research facilities within the Air Force and between the Air Force and Navy in the areas of impact acceleration and high sustained acceleration. There is no duplication in facilities in the Army or between the Army and the other military departments.

A review of the threat faced by United States ground forces in Europe reinforces the need for a dedicated helicopter aeromedical research facility to support the Army's

expanded use of helicopters in a high intensity conflict.

As new and more efficient helicopters are developed, a new generation of physiological problems are created and must be solved if men are to operate helicopters safely and effectively. Among these problems are severe visual restraints, crash survivability, life support equipment needs, combined stresses, new demands on night vision, and sustained performance of aircrews. The need for helicopter aeromedical research continues longitudinally and increases significantly with the development of more complex and sophisticated helicopters.

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ARMY AEROMEDICAL RESEARCH

INTRODUCTION

Early pessimists of flight maintained that the atmosphere above the ground could not maintain life, but on 19 September 1783, Joseph and Etienne Montgolfier, inflated their balloon and sent aloft in a wicker cage a sheep, a chicken, and a duck. The balloon reached a height of 1,440 feet and drifted for eight minutes before coming to rest 10,200 feet from the starting point. The animals were examined closely to determine any ill-effects from their flight. They were unharmed by the experience thus paving the way for the first flight by man. One month later, 15 October 1873, Monsieur Jean Francois Pilatre de Rozier became the first man to ascend in a balloon. Monsieur de Rozier ascended to eighty feet, which was the maximum length of the rope, and remained aloft for four and one-half minutes. Subsequent restrained flights were so successful that a free balloon flight was planned with two condemned criminals as passengers. The two criminals were selected with the understanding that if they came down alive, they would be given their freedom. Monsieur de Rozier and Marquis Francois Laurent d'Arlandes objected to the criminals having the honor of the first free

balloon flight and persuaded King Louis XVI to allow them to make the flight. The first free flight took place on 21 November 1783. The flight of Monsieur de Rozier and Marquis d'Arlandes across Paris lasted twenty-five minutes and covered six miles. On this first flight they suffered no ill-effects. In a subsequent flight two months later, however, Monsieur de Rozier reported severe pains in his ears. This was the first ill-effect noted during flight and one which remains important to air travelers today.[1]

In 1862, James Glaisher and Henry Coxwell ascended to a reported altitude of 29,000 feet. During the ascent Glaisher lost consciousness and Coxwell became partially paralyzed. Both men would have died if Coxwell had not seized the valve cord between his teeth and released the gas from the balloon by nodding his head.[2]

The ill-effects of flight on man were further demonstrated by the "Tragic Tissandier" disaster. On 15 April 1875 Gaston Tissandier, Joseph Eustache Croce-Spinelli, and Henri Theodore Sivel ascended in a balloon to 28,000 feet. Paul Bert, a friend of Tissandier and the first physician to study the effects of flight on man, advised him to use oxygen in the ascent. Since the oxygen supply was small, the three men decided not to use it until they had reached a very high altitude. This proved to be a fatal mistake. As the men reached higher altitudes, their coordination and mental abilities became impaired. Tissandier survived, but

Croce-Spinelli and Sivel died. Tissandier provided a vivid description of the latter part of the flight:

> I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 22,000 feet . . . Torpor had seized me. I wrote nevertheless . . . though I have no clear recollection of writing. We are rising. Croce is panting. Sivel shuts his eyes. Croce also shuts his eyes . . . at 24,000 feet the condition of Torpor that overcomes one is extraordinary. Body and mind become feebler . . . There is no suffering. On the contrary one feels an inward joy. There is no thought of the dangerous position; one rises and is glad to be rising. I soon felt myself so weak that I could not even turn my head to look at my companions . . . I wished to call out that we were now at 26,000 feet, but my tongue was paralyzed. All at once I shut my eyes and fell down powerless and lost all further memory.[3]

Tissandier was describing a classic case of altitude hypoxia, a condition that can affect aircrews today.

Several years later Paul Bert proved that the tragic death of Croce-Spinelli and Sivel was caused by the low volumn concentration of oxygen at altitude. Bert conducted his experiment in a homemade pressure chamber in which he ascended to an equivalent altitude of 29,000 feet. Accompanying Bert in the chamber was a bird, a rat, and a candle. As Bert ascended to altitude he became dizzy and his pulse increased from sixty to eighty-six. The bird at altitude was close to death; the rat was uneasy and the burning candle had turned very blue. Bert began to breathe oxygen; his dizziness disappeared and his pulse returned to sixty. Bert's experiment proved that aircrews ascending to high altitudes must use oxygen in order to survive.[4]

For fifty years, including the period before World War I, Bert's method of carrying oxygen in a tank with a hose for insertion into the mouth satisfied the needs of aircrews. However, as the strategy and tactics of aerial war made operations at higher altitudes more desirable and aircraft design technology permitted flights up to altitudes of 40,000 feet during World War II, new problems arose. Bert's simple oxygen system was no longer adequate because his hose delivery method permitted dilution of the oxygen supply. Once again, aeromedical research was called upon to improve the oxygen supply system so that man could fly at higher altitudes. Facial masks with a regulating valve opening only during expiration were developed. With these new facial masks, it was possible to deliver undiluted oxygen to the aircrews.[5]

As the above examples demonstrate, man has consistently experienced physiological problems during flight which limited the performance capabilities of his aerial machines. Man had been freed from his earthbound existence only to find that the full utilization of his new machine was restricted by his inability to live at high altitude.[6]

AEROMEDICAL RESEARCH

Aeromedical research is synonymous with aviation medicine. The two cannot be separated, since both disciplines are concerned with man in the flight environment and the removal of those factors which degrade his performance.

Furthermore, the aviation medical officer, better known as the flight surgeon, participates and directs both disciplines. Major General Spurgeon Neel, Commander, U.S. Army Health Services Command and a Master Flight Surgeon, recently described aviation medicine as having two parts similar to the two sides of a common coin. On one side of the coin is "Aviation Medicine or the contributions of medicine to aviation."[7] These contributions have enhanced man's ability to perform in the flight environment. One of the earliest contributions was Paul Bert's study of the effects of hypoxia on man and the recommended use of oxygen in high altitude balloon flight. The development of faster and more complex aircraft exposed man to new acceleration forces, noise, vibration, and other environmental forces which tested the limits of man's ability to survive and often compromised his ability to perform. Aviation medicine provided the technology which enabled man to survive and function in his new environment. Today's contributions range from advanced G protection and ejection technology in high performance aircraft to improved crash protection in helicopters.

Aeromedical research falls into the aviation medicine category and has as ". . . its main objective the very survival of man" in both the natural and mechanical force environment of flight.[8] For aviation medicine embraces all of the medical sciences. It includes the complete medical spectrum from the ". . . routine work of physicians treating

disease, the establishment of physical standards, the selection of personnel and the practice of preventive medicine" to efforts engaged in research to determine the effects of flights on man.[9] Aeromedical research also seeks a clear understanding of man's capabilities and survivability for each new aircraft to obtain maximum aircrew effectiveness and mission accomplishment.

On the other side of the coin is medical aviation or the contributions of "aviation to medical capabilities, operations, and effectiveness."[10] These contributions have enabled man to rapidly move battlefield casualties directly to the hospitals capable of providing the best care for specific injuries, as well as, provide a more effective and efficient use of all medical resources.

BACKGROUND TO THE PROBLEM

The major problems confronting aeromedical research in 1977 are lack of medical and physical scientists, limited funds combined with inflation, and the fact that six Department of Defense laboratories are engaged in aeromedical research.[11] There are a number of key factors which have a bearing on these problems. Lack of manpower and the inability of the military departments to attract and keep professional scientists are important factors that degrades the aeromedical research effort. Major Vance, in his study entitled "Recruitment of Physicians for the Active Army, 1975-1980," projects

that the Army will experience a decrease in the number of physicians in fiscal year 1977, 1978, and 1979. The educational facilities available to train and the number of active duty spaces allocated for training are limited.[12] This directly contributes to the nonavailability of professional manpower. The total Army residency program is considerably less than the Army's requirements for professional manpower.[13] The problems of limited manpower have already stimulated the Surgeon General of the Navy to advocate a single medical corps.[14]

The Army Medical Departments (AMEDDS) career management policies further compound these problems. Colonel Robert W. Bailey, Commander, U.S. Army Aeromedical Research Laboratory, recently described this problem:

> We [the Army] are our own worst enemy. There is no career in the research field in the Army. A scientist is a guy who has nine years of his life as an absolute minimum in College. We offer him a career in the Army as a Medical Service Corps officer or a Medical Corps officer. As a Medical Service Corps officer he gets no incentive pay, he gets no acknowledgement for all the extra effort he has given.
>
> Some of these people are actually trained by the Army. As soon as their pay back time is up they leave [the Army] and go to the University environment. It's more lucrative and they have more [research] freedom. We recently had a young microbiologist, who wanted to make the Army a career. We [AMEDDS] could not offer him a career. If a guy is in love with research and [research] is his prime goal, he departs the service and gets a civilian job.
>
> Industry spots these people in a hurry and [they] offer him a better salary, a health program for him and his family, a retirement program not much different than the Army's, plus stock options in the company after five years. So you [the Army] make him, manufacture him, identify him, train him, and then destroy him

[because he has no research career in the Army].

This is a very serious problem because recently, my boss, General Augerson, sent me a telegram and asked, what can USAARL do to help win the next war? My reply, if we haven't done it by the time the next war starts, we are not going to get it done in time to be of much benefit to the operational guy. The one thing that we can do for the operational guy and the only thing we have left is that, as operational problems develop, we can generate research teams and send them to the field to review the problem and offer the commander expert advice on how, in our opinion, he can best solve his problem. Civilian scientists cannot be sent to the field to answer these problems. [We must always have] as a nucleus a hard core of military people that can talk with the operational types, that understand the operational side and do the job. As we lose military personnel, we fill the vacancy with civilians and after a military lab has been in existence several years the lab becomes a vertical lab [mostly civilian] who do not understand the operational problems.

Until we [the Army] get a career research program so the productive military scientist can have a career, we will not keep them.[15]

Inflation combined with limited funds directly influence the costs of new weapon systems. The total research and development funds committed to aeromedical research have generally diminished and inflation continues to aggravate the reduction in funds. Colonel Stanley C. White, Military Assistant for Medical and Life Sciences in the Department of Defense's Office of the Defense Director for Research and Engineering, in a speech before the 1976 Aerospace Medical Association meeting described the impact of limited funds:

My forecast for the future suggests that you should not expect major increases in funds. . . . At best, we might expect to receive sufficient increases in funds to compensate for inflation.

The message I draw from this gloomy funds picture is that all of us must get the maximum return for the dollar invested. Parochial and vested interest programs must

> step aside for those of higher priority and emphasis. This will require us to become more efficient in the use of available personnel and facilities. The cost of facilities and the specialized equipment are also skyrocketing. The limited funds that will be available for new facilities must be carefully marshalled to insure that they are available for application to those special facilities that will be needed to meet the priority capabilities that do not exist.
>
> In view of the fund constraints . . . I am concerned that our ability to conduct research--at a tempo that will meet the need for data and design criteria for future systems--. . .. will be threatened.[16]

The effect of inflation is typified by Secretary of Defense James R. Schlesinger's comments to congress in the annual Defense Department report:

> Overall, considering pay and purchases together, we had forecast inflation of some 23 percent from FY 1973 to FY 1976, and are now facing 37 percent.
>
> The inflation rates in most basic materials used by defense industries have been rising at unanticipated and virtually unprecedented rates. The extraordinary inflation of the past year has had a severe impact on DOD's procurement of congressionally approved weapon systems.
>
> This unforeseen inflation is the primary reason that our FY75 buying power has been so weakened. It is also the reason that our current FY 1976 program--in spite of a sharp increase in dollar levels--is far below the real term levels we had projected a year ago.[17]

For comparative purposes, the medical research program amounts to approximately 0.17 percent of the defense budget, 1.7 percent of defense research, 4.5 percent of defense health, and 0.5 percent of the federal health program.[18] A summary of fiscal year 1978 aeromedical research funding for each military department is provided in Table 1.

Table 1

FY 77 Funding-Mechanical Forces
[Aeromedical Research]
($ in thousands)

ARMY	NAVY	AIR FORCE	TOTAL
1,104	3,491	6,628	11,223

SOURCE: Department of Defense, Office of the Defense Director for Research and Engineering, Technology Coordinating Paper, Medicine and Biological Sciences, n.p., January 1977, A-19, appendix 2, Table A-2.

Table 2 shows the military departments and the locations of the laboratories.

Table 2

Aeromedical Research Laboratories

ORGANIZATION	MILITARY DEPARTMENT
USAF School of Aerospace Medicine, Brooks AFB, Texas	Air Force
6570 Aerospace Medical Research Laboratory, Wright-Patterson AFB, Ohio	Air Force
Naval Aerospace Medical Research Laboratory, Pensacola Naval Air Station, Florida	Navy
Naval Aerospace Medical Research Laboratory Detachment, Michoud, Louisiana	Navy
Crew Systems Department, Naval Air Development Center, Warminster, Pennsylvania	Navy
U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama	Army

SOURCE: Department of the Army, Navy, and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration and Impact, n.p., 18 July 1975, Table 1.

These six laboratories have many similarities. For example, all of the laboratories study the effects of the flight environment on man. The nature of the flight environment exerts a combination of physiological and psychological factors on man. These factors include a combination of acceleration forces, vibration forces, visual and hearing restraints, and unusual stresses which are peculiar to the flight environment regardless of the type airplane or helicopter being flown. Thus, there appears to be duplication of effort.

In view of these problems, it is relevant to ask whether or not there is a need for a helicopter aeromedical research capability.

THESIS PROBLEM STATEMENT

The thesis problem statement is best described by two questions: Is there a need for a helicopter aeromedical research capability? And/or, are the present Department of Defense helicopter aeromedical research capabilities adequate?

Assumptions

Fundamental assumptions of the study are:

a. Aeromedical research must be of the highest quality to protect and enhance the performance of aircrews.

b. Continuation of an aeromedical research program is essential to the requirements and the effectiveness of the military departments in combat.

THE PURPOSE OF THE STUDY

The purpose of the study is to determine the need for a helicopter aeromedical research capability as measured against the current Department of Defense research activities.

To accomplish this it is necessary to: (1) review the history of helicopter aeromedical research; (2) examine the current aeromedical research programs, facilities, and capabilities; (3) determine the extent of the areas of coordination and interdependence; and (4) determine if there is a need for a dedicated helicopter aeromedical research capability.

Definitions

The majority of the terms used throughout the study are standard terms defined by the Advisory Group for Aerospace Research and Development. The definition of certain terms are expanded for clarity.

-Aviation Medicine: That branch of medicine dealing with the effects on man of the environment of flight. More specifically, the effects of flight, the performance by man of those tasks inherent in the control of aircraft and the prevention or alleviation of the physiological, psychological, and pathological effects of stresses associated with flight.[19]

-Aeromedical: Pertaining to Aviation Medicine (q.v.)[20]

-Aeromedical Research: That branch of aviation medicine which deals with basic and applied research.

-Biodynamics: The biological effects of mechanical forces, such as brief and prolonged acceleration, reduced or absent gravity, and vibration.[21]

-Bioengineering: The application of engineering principles to the solution of biological problems, for example, remote handling devices, life support systems, controls, and displays.[22]

-Blast: Pressure created from firing weapon systems.

-Downwash: Force of air created by the rotor system of a helicopter hovering in ground effect.

-Dynamic Pressure: The aerodynamic forces acting on a body in circumstances of relative motion within the atmosphere. The force is of importance in the assessment of the stresses applied to the body during escape from a moving aircraft.[23]

-Wind Blast: The effect of exposure to high relative velocity in a gaseous medium, e.g., rapid motion in still air or static exposure to fast-moving air.[24]

CHAPTER I

ENDNOTES

[1]Charles D. Chandler and Frank P. Lahm, How Our Army Grew Wings (New York: Ronald Press Company, 1943), pp. 3-5; see also Malcolm C. Grow and Harry G. Armstrong, Fit to Fly (New York: D. Appleton-Century Company, 1941), pp. 1-2.

[2]Detlev W. Bronk, "Human Problems in Military Aviation," Smithsonian Report for 1945 (Washington: Government Printing Office, 1946), p. 402.

[3]Grow and Armstrong, Fit to Fly, pp. 2-3.

[4]John F. Fulton, "Medicine, Warfare, and History," Smithsonian Report for 1954 (Washington: Government Printing Office, 1955), p. 435.

[5]Bronk, "Human Problems in Military Aviation," pp. 402, 405.

[6]Detlev W. Bronk and others, Advances in Military Medicine (Boston: Little, Brown and Company, 1948), p. 207.

[7]Spurgeon Neel, "A Doctor Looks at Army Aviation," U.S. Army Aviation Digest, October 1976, p. 1.

[8]Lynn S. Beals, Jr., "Some Considerations of Aeromedical Research," Aviation Medicine 23 (June 1952), p. 297.

[9]Carl E. Wilbur, "Aviation Medicine," in The Human Machine, ed. C. W. Shilling, (Annapolis: United States Naval Institute, 1955), p. 239; and Thomas J. Bourgeois, "Aviation Medicine," U.S. Army Aviation Digest 13 (September 1967), p. 27.

[10]Neel, "A Doctor Looks at Army Aviation," p. 1.

[11]"Efforts Fail to Boost Dwindling MD Ranks," Air Force Times, 26 April 1976, p. 10; "New School Won't Fill Doctors Needs," Air Force Times, 16 July 1976, p. 2; Stanley C. White, "The Next Decade . . . A Research Challenge and an Opportunity," Aviation, Space and Environmental Medicine 46 (August 1975): 1056; Department of Army, Navy, and Air Force. Integrated Plan for Research on the Human Effects of Acceleration, Vibration and Impact, n.p., 18 July 1975.

[12]William M. Vance, "Recruitment of Physicians for The Active Army 1975-1980" (Masters Thesis, U.S. Army Command and General Staff College, 1975), pp. 21-24. In April 1977 the Surgeon General revealed that the Army would be about 530 military physicians short of the need by the end of FY78. Gene Famiglietti, "Shortage of 530 Doctors Expected," Army Times, 18 April 1977, p. 25.

[13]Ibid.

[14]"Single Medical Corps Urged," Air Force Times, 16 July 1976, p. 2.

[15]Interview with Colonel Robert W. Bailey, Commander, U.S. Army Aeromedical Research Laboratory, Ft. Rucker, Alabama, 28 December 1976.

[16]Stanley C. White, "The Next Decade--A Research Challenge and an Opportunity," Aviation, Space, and Environmental Medicine 46 (August 1975): 1056.

[17]Department of Defense. Annual Defense Department Report FY 1976 and FY 1977, by J. R. Schlesinger (Washington: Government Printing Office, 1975), pp. B-1, C-1.

[18]William S. Augerson, "Medical Research--Contributes to Effectiveness of Man," Defense Management Journal 1 (January 1974), 8.

[19]D. I. Fryer, ed., Glossary of Aerospace Medical Terms, North Atlantic Treaty Organization Advisory Group for Aerospace Research and Development, AGARDograph 153, (London: Technical Editing and Reproduction Ltd., 1971), p. 3.

[20]Ibid., p. 1.

[21]Ibid., p. 4.

[22] Ibid.

[23] Ibid., p. 7.

[24] Ibid., p. 20.

CHAPTER II

HISTORICAL REVIEW OF AEROMEDICAL RESEARCH

EARLY AEROMEDICAL RESEARCH

Aeromedical research actually began with Paul Bert, the French physician, and John Jeffries, an American physician. In January 1785, Dr. Jeffries, a Boston physician temporarily practicing medicine in London, and Francois Blanchard, a French balloonist, became the first to cross the English Channel in a balloon.[1] Dr. Jeffries made several flights with Blanchard in which he conducted scientific experiments pertaining to the temperature, pressure, and composition of the air at altitude. Thus, Bert and Jeffries were the first physicians to conduct scientific experiments concerning man in flight. Following the experiment of these two doctors, little medical interest was shown in the physiological effects of flight until after the invention of the airplane.[2]

Early interest in aeromedical research centered on pilot selection and the general well-being of the man in flight.[3] This was particularly true prior to and during World War I. The absence of physical and mental difficulties among German pilots during World War I pointed to the success of Germany's pilot selection program. In contrast, Great Britain did not have a pilot selection program, and the

result at the end of the first year of war was disastrous. After the first year of war, the British ". . . determined that of every 100 aviators killed, 2 met death at the hands of the Germans, 8 died because of defective aircraft, and 90 died because of their own deficiencies."[4]

As aviation technology advanced the airplane, man was subjected to a combination of natural and mechanical force environments which degraded his performance and effected his ability to operate the airplane safely. This new environment subjected man to a combination of noise, vibration, acceleration and physiological forces, as well as, reduced oxygen supply and atomospheric pressure. Aviation medicine recognized early that human tolerance could be exceeded in flight, and therefore, man himself imposed restrictions on aircraft performance.[5]

ARMY AIR CORPS MEDICAL SERVICE

The Army Air Medical Service was organized 28 April 1917. In October 1917, the Medical Research Board and the Medical Research Laboratory were established, and by January 1918 the first Medical Research Laboratory began operation at Hazelhurst Field, Mineola, Long Island. The laboratory was organized into six departments: Otology, Cardiovascular, Physiology, Psychology, Psychiatry and Neurology, and Ophthalmology. The prime purpose of the laboratory was to study the effects of flying on man.[6] In 1919, the laboratory was moved

to Mitchel Field, New York, where the name of the laboratory was changed to The Medical Research Laboratory and School for Flight Surgeons. The name of the laboratory was changed to reflect the expansion of the mission of the laboratory to include a four month training course for flight surgeons. In 1922 research became a secondary mission and the name of the laboratory was changed to The School of Aviation Medicine. The school was transferred in 1927 to Brooks Field, San Antonio, Texas, and moved in 1931 to Randolph Field, San Antonio, Texas, which was the site of the Air Corps Primary Training Center. This location provided a close association with the primary training center and allowed the school to function more effectively as a teaching and research institution. This facility evolved into the U.S. Air Force School of Aerospace Medicine and is presently located in permanent facilities at Brooks AFB, San Antonio, Texas.

During the early 1930s, military aircraft design increased their speed and altitude and, once again this resulted in exceeding man's physiological capabilities. This generated a need for research in aircrew equipment and materiel to allow for normal aircrew operations under the combined stresses and hazards of increased airspeed and altitude. These considerations prompted Major Malcolm C. Grow, Post Flight Surgeon at Patterson Field, Ohio, to recommend the establishment of a Medical Laboratory at Wright Field, Ohio, where the aircraft engineering and testing facility of the air corps were

located. On 19 May 1935, the chief of the Army Air Corps directed the establishment of a Physiological Research Laboratory which was completed 1 January 1937. This laboratory has remained at Wright Field and is now the 6570th Aerospace Medical Research Laboratory.[7]

During World War II, the demands of national security imposed on the military the responsibility of exploiting each new development in aircraft to gain a tactical and strategic advantage. Consequently, aeromedical research became a coordinated effort between civilian institutions and the military. During this time, the majority of research was carried out under the auspices of the National Research Council. The council organized a committee on aviation medicine to investigate the physiological dangers and stresses of aerial combat.[8] Under the direction of this committee, the aeromedical research programs were carried out under contract with individual civilian laboratories, foundations, and universities.[9]

SEPARATION OF AIR FORCE AND ARMY

After World War II, an autonomous United States Air Force was established with its own medical service. The Army's aviation medical officers, who were flight surgeons, transferred to the Air Force and left the Army with one qualified aviation medical officer. Army aviation depended almost exclusively upon the Air Force for aviation medicine until 1951.[10]

After the Air Force Medical Service was established, LTC Rollie M. Harrison, MC, a former Army Air Corps flight surgeon was the only Army medical officer who provided an Army aviation medicine program responsible for the medical care of Army aviation personnel. LTC Harrison carried out his program at Fort Sill, Oklahoma, which was the home of the Army Signal School and the only Army element with aviation assets. In March 1951, Major Spurgeon Neel, MC (Now Major General, Commander, U.S. Army Health Services Command) became the first Army physician trained by the Air Force in aviation medicine.[11] Largely through MG Neel's foresight and efforts, Army aviation medicine progressed and Army aeromedical research evolved.

As the Army relied more and more on low-speed aircraft and helicopters for combat support, MG Neel (then Commander, Lyster Army Hospital, Ft. Rucker, Alabama) recognized the need for an aeromedical research facility to provide the necessary medical support. Consequently, in June 1960 the first Army Aeromedical Symposium was hosted by the Naval School of Aviation Medicine at Pensacola, Florida. The symposium was sponsored by the U.S. Army Board of Aviation Accident Research (now, U.S. Army Agency for Aviation Safety) and emphasized Army aviation medicine research relevant to aviation safety. The symposium, attended by senior Army medical officers, aviation medical officers, and aviation safety experts, provided for the first time the opportunity to increase the Army's awareness of Army aviation research/medicine and its

role in Army aviation.[12] As a result, the U.S. Army Aeromedical Research Unit, conceived by MG Neel (then COL Neel) was officially established as a Class II activity under the jurisdiction of the Surgeon General, United States Army, at the United States Army Aviation Center, Fort Rucker, Alabama.[13] In October 1962, the aeromedical unit was assigned to the newly founded United States Army Medical Research and Development Command with the mission to provide aviation medical research in direct support of all Army aviation and airborne activities.[14] The U.S. Army Aeromedical Research Unit was redesignated the U.S. Army Aeromedical Research Laboratory on 27 January 1969, giving the laboratory coequal status with the eight other medical laboratories of the Medical Research and Development Command.[15]

CHAPTER II

ENDNOTES

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[4]Thomas J. Bourgeois, "Aviation Medicine," U.S. Army Aviation Digest 13 (September 1967), p. 25.

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[7]Military Medical Manual, pp. 511-514.

[8]Detlev W. Bronk and others, Advances in Military Medicine (Boston: Little, Brown and Company, 1948), pp. 207-209.

[9]Beals, "Some Considerations of Aeromedical Research," p. 297.

[10]Roland H. Shamburck and Spurgeon H. Neel, "Army Aviation Medicine," U.S. Army Aviation Digest, 9 (January 1963): 34; see also LTC William H. Hark and LTC Chester L. Ward, "Army Aviation Medicine in Vietnam" (report based on personnel experiences in Vietnam), p. 1.

[11]Shamburck and Neel, "Army Aviation Medicine," p. 35.

[12]Ibid., p. 36.

[13]Department of the Army, General Orders 39, para 3, United States Army Aeromedical Research Unit, 6 July 1962.

[14]Department of the Army, Office of the Surgeon General, General Orders 41, para 1, United States Aeromedical Research Unit, 4 October 1962.

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CHAPTER III

PRESENT AEROMEDICAL RESEARCH ACTIVITIES

ARMY

The Army's aeromedical research program is conducted at the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama. The major research activities of the laboratory are in the medical aspects of Army avaiation, airborne operations, and air assault operations. The laboratory is also responsible for performing research in the areas of vision, hearing, man/machine integration, and the medical problems associated with nonmedical materiel.[1]

Facilities

The U.S. Army Aeromedical Research Laboratory is housed in sixteen World War II single story wooden buildings, occupying 73.2 thousand square feet.[2] Among the items of equipment and facilities available in support of research are: the Helmet Test Facility, used for medical evaluation of head protective devices; Multi-Axis Helicopter Vibration Simulator; Helicopter Anti-Buffet and Turbulence Facility; Multi-Axis Helicopter Flight Simulator Facility; Helicopter Inflight Monitoring System; Bioengineering Laboratory, which includes the Life Support Equipment Retrieval and Analysis

Facility; Aviation Medicine Laboratory, which includes a biochemistry and physiological data acquisition capability; Aviation Psychology Laboratory; Vision Laboratory; Hearing Laboratory with anechoic chambers; a medical Electronics Laboratory; Hybrid Computer facilities with associated data analysis; and incidental equipment for helicopter and biomedical instrumentation.[3] The specialized facilities are summarized in Annex A.[4]

Capabilities

The U.S. Army Aeromedical Research Laboratory at Fort Rucker has an authorized strength of 106 military and civilian personnel of which fifty-three percent presently hold technical or professional degrees. The research team includes medical, psychological, physiological, and engineering scientists, as well as, helicopter crews experienced in conducting medically oriented flight tests. Medical doctors assigned to the laboratory hold certification in one of several specialities--cardiology, internal medicine, anesthesiology, orthopedics, and aerospace medicine. Doctorial level scientists are also assigned in the disciplines of veterinary medicine, physics, biochemistry, psychology, and physiological optics. Masters level scientists serving on the team include chemists, physicists, and biomedical, aeronautical, biomechanical, and electrical engineers.[5]

AIR FORCE

The Air Force aeromedical research efforts are centered at the 6570th Aerospace Medical Research Laboratory (AMRL), Wright-Patterson AFB, Ohio, and the U.S. Air Force School of Aerospace Medicine, (USAFSAM), Brooks AFB, Texas.

Facilities

6570th Aerospace Medical Research Laboratory. Research at AMRL concentrates on the physiological effects of maneuvering high performance aircraft, vibration effects characteristic of high performance aircraft, weapon delivery accuracy, tactical warfare simulation, threat detection, and countermeasures.

The AMRL is housed in permanent structures consisting of 143.2 thousand square feet and the total authorized strength of the laboratory is 243 military and civilian personnel. Specific items of equipment and facilities available in support of its research are: The Dynamic Environmental Simulator; Vertical Accelerator, Vertical Acceleration Tower; specialized Vibration Tables (not specifically designed for helicopters); incidental equipment for high performance aircraft simulation and cockpit mockups; and computer facilities with associated data acquisition and analysis. The specialized facilities are summarized in Annex B.[6]

USAF School of Aerospace Medicine. The USAFSAM facility occupies 627.4 thousand square feet consisting of

several permanent structures. This organization is authorized a total of 953 military and civilian personnel. Research at USAFSAM focuses on improving pilot performance in strategic and fighter aircraft, invasive physiologic studies, advanced G-suit design criteria, environmental stress, and visual-motor performance. Items of specialized equipment and facilities include: Human Centrifuge; Rotational Flight Simulator; Small Animal Centrifuge; Optic and Audiology Laboratory; Aeromedical Evaluation and Consultative services; and various test cells and chambers. The facilities are summarized in Annex C.[7]

Capabilities

The Air Force has developed a centralized capability to conduct research on major developmental Air Force weapon systems at the 6570th Aerospace Medical Research Laboratory. The facilities at Wright-Patterson AFB provide for cross-utilization of laboratory supporting services and research personnel with the Air Force's major aeronautical hardware laboratories and technology users (system program offices). Approximately seventy-eight percent of the AMRL staff is composed of technical and professional personnel who hold Bachelor's, Master's and Doctorate degrees in medicine, physiology, bioengineering and a variety of physical science disciplines. Forty-six percent of the USAFSAM staff hold Bachelor's, Master's or Doctorate degrees in a wide range of disciplines. The USAFSAM research staff represents a

resource in the Air Force that has been developed over a thirty-five year period of active participation in support of Air Force mission requirements.[8]

NAVY

The main thrust of the Navy's Aerospace Medical Research program is carried out at three major installations: the Naval Aerospace Medical Research Laboratory (NAMRL), Pensacola, Florida; Naval Aerospace Medical Research Laboratory Detachment, Michoud, Louisiana (NAMRL-Det); and the Crew Systems Department, Naval Air Department Center (NADC), Warminister, Pennsylvania.

Facilities

Naval Aerospace Medicine Research Laboratory, Pensacola, Florida. This laboratory investigates vestibular mechanisms, motion sickness, fatigue, physical standards, and physiological effects of nonionizing radiation. The laboratory occupies several permanent facilities totaling 169.7 thousand square feet. Among the items of equipment and facilities available in support of research are: the Slow Rotation Room, a modified human centrifuge for studies of the effects of spinning; the Human Disorientation Device; the Coriolis Acceleration Platform; a high density electromagnetic field assembly and a magnetometer for studies of electrical fields; incidental equipment for studies of high intensity noise; and

computers with associated data analysis facilities. These facilities are summarized in Annex D.[9]

Naval Aerospace Medical Research Laboratory, Detachment, Michoud, Louisiana. The research at the Navy's Michoud Detachment focuses on surface effect ships (hydrofoils) and biomedical tolerance standards for crashworthy aircrew protection design criteria. The NAMRL-Det concentrates on the needs for optimum head-neck and torso protection, development of physiologically based test analogs, and development of biomedical standards for seaborne platform ride quality and handling quality design. Among the facilities and equipment available in support of this research are: the Horizontal Accelerator; the Vertical Accelerator; and extensive data acquisition and reduction facilities. These facilities are summarized in Annex E.[10]

Crew Systems Department, Naval Air Development Center, Warminster, Pennsylvania. The Crew Systems Department is one of five research departments which make up the Naval Air Development Center (NADC). The Crew Systems Department provides a coordinated research and development program to meet the Navy's requirements of tactical and attack carrier based, high performance, fixed wing aircraft, and over-water operations in the areas of aerospace medicine, life sciences, aircrew equipment, and human factors engineering, including force field dynamic simulation.

The Crew Systems Department occupies a separate facility that houses the dynamic flight simulator. This simulator supports engineering studies of the Naval Air Systems Command and biomedical studies of the Bureau of Medicine. Special instrumentation provides for pilot controlled closed loop simulation, barometric pressure changes, noise, heat, sky-glare, and buffet to simulate handling qualities and performance characteristics of Navy fixed winged aircraft. A modular cockpit enclosure is matched to the dynamic flight simulator's gondola, providing the flexibility to simulate specific Navy cockpit configurations. Supporting facilities for medical evaluations and data processing are provided.

Other facilities which support the Crew Systems Department research efforts are: the Horizontal Accelerator, a Hydropneumatic Catapult, the Ejection Seat Tower; the Vertical Decelerator; Environmental Test Facility, altitude chambers used for environmental testing, and long term physiological studies, as well as, decompression studies; hyperbaric facilities, Thermal Test Facility; and a Under-Water Research Facility. These specialized facilities are summarized in Annex F.[11]

Capabilities

The Navy Aeromedical Research Program is organized around specific facility capabilities at the Naval Aerospace Medical Research Laboratory, Pensacola, Florida, the Naval

Aerospace Medical Research Laboratory (NAMRL) Detachment at Michoud, Louisiana, and the Naval Air Development Center, Warminster, Pennsylvania. The research efforts at NAMRL are primarily concerned with motion sickness and disorientation effects of angular acceleration forces. The civilian and military scientists responsible for this research activity are recognized authorities on prevention of disorientation and vestibular disturbances in flight and on the physiological effects of nonionizing radiation. These scientists have devoted many years of intensive effort to reduce the disabling effect of motion sickness and prevent disorientation accidents. The NAMRL staff has a total authorized strength of 149 military and civilian personnel.

In 1970, the NAMRL Detachment was established to conduct a research program on human dynamic response to impact acceleration in order to prevent aircrew impact injury. A team of forty scientific and technical personnel, in addition to twenty-one volunteer experimental subjects, are assigned to accomplish the impact research effort. Sixty percent of the scientific staff hold university degrees and forty percent of these are at the doctoral level. The integrated team consists of experts in medicine, human and primate physiology, electronic and mechanical engineering, and computer sciences.

The Naval Air Development Center operates the Dynamic Flight Simulator to satisfy a wide variety of engineering

test, crew familiarization, and aeromedical research requirements. A large multi-disciplinary team of engineering, life support, and medical scientists are available within the Crew Systems Department of NADC to conduct the planned research on the human effects of maneuvering acceleration and combined mission stress. Experienced personnel are assigned to several supporting department organizations, including the Performance Measurement Branch, Acceleration Physiology Branch, Environmental Physiology Branch, Biochemistry Branch, Life Support Protective Equipment Branch, and Dynamic Flight Simulation Branch. The Crew System Department consists of 122 military and civilian personnel.[12]

AEROMEDICAL RESEARCH PROGRAMS

The aeromedical research efforts of the three military departments are structured to support the weapon and/or aircraft systems that are required to support their assigned mission responsibilities. The Air Force aeromedical research activities are primarily concerned with the medical efforts of land-based, high performance bombers and fighter/attack aircraft to effectively discharge the mission of strategic and tactical air operations.[13] The Navy's mission responsibilities are to secure adequate control of the sea lines of communication in order to reinforce and resupply deployed forces and to project naval power ashore utilizing carrier based aircraft, naval gunfire, and amphibous forces.[14] The Navy's aeromedical research focuses on the medical aspects

of carrier-based, high performance fighter/attack aircraft, V/STOL aircraft and ships, as well as, special missions such as antisubmarine and underwater operations.[15] The primary thrust of the Army aeromedical research efforts are related to the medical aspects encountered in helicopter, airborne, and land operations.[16] The areas of research planned by each service are summarized in Table 3.

There is a natural research overlap in some areas; however, the three military departments have developed complimentary research programs, serving their unique, as well as, common requirements.

The three military department's aeromedical research activities are predominately in the areas of: Impact Acceleration; High Sustained Acceleration; Blast, Windblast, Downwash and Dynamic Pressure; Spatial Orientation/Disorientation (vision/optics); Vibration; Noise; and Combined Stress.

Impact Acceleration

The Army's efforts in impact acceleration focus on biomedical design criteria for land vehicles, helicopters, and light aircraft. The Army does not have a basic research program in determining the effects of impact on the tissue and organ properties of the body. Major research efforts in this area are conducted by the Air Force and the Navy. The Army has agreed to use the data generated by the Navy and the Air Force in this area to develop physiologically based

Table 3

Areas of Aeromedical Research

USAF	ARMY	NAVY
	REQUIREMENTS BASE	
Bomber operations (strategic)	Helicopter Operations	V/STOL operations (Carrier/ land based)
Fighter/attack operations (land based)	Attack	Fighter/attack (Carrier, land based)
Logistic operations (strategic)	Cargo	Ship operations
Helicopter operations (Rescue)	Utility	High Speed Surface Amphibious Submarine
	Med-Evac	
	Light Aircraft Operations (Liaison, Recon)	Helicopter operations (Rescue, antisubmarine)
	Ground Vehicle Operations	
	TECHNOLOGY BASE	
Medical aspects of high performance strategic and tactical aircraft	Medical aspects of helicopters, ground vehicle and airborne operations	Medical aspects of high performance fighter/attack aircraft, V/STOL and ships
	GOALS	
Enhance total system performance and effectiveness. Prevent injuries or death in systems operations.		

SOURCE: Department of the Defense, Technology Coordination Paper, Medician and Biological Sciences, January 1977, Appendix 2, A-54.

analogues and test methods for helicopters, airborne, and land vehicle operations. The primary goal of this research is to improve personnel restraint systems, protective equipment, seat design, escape systems, body armor, and to prevent injuries, as well as, enhance performance and military effectiveness.[17]

At the present time, major impact problems exist for the Army in helicopter operations. For example, malfunctions of protective equipment such as restraint systems and crew seats; also improper flight procedures below safe autorotation altitudes result in high sink rate crashes which transfer combined vertical, forward and/or lateral impact forces to aircrews. This causes excessive casualties in helicopter accidents. Army estimates for the 1967-72 time period indicated a 37 percent excess mortality as a result of inadequate crashworthiness design.[18] Another aspect of the helicopter impact problem relates to head injury and the need for effective protective helmets. Design is compromised by adding target acquisition systems and optical sights to the helmet. As a result, valid human protection criteria is needed.[19]

The Navy's research focuses on determining the human head/neck/torso response to impact acceleration and defining the human tolerance limits to head concussion. The Navy's goal in this effort is to predict injury to provide better biomedical design criteria for protective systems.[20] The major result of ditching and "over-the-side" carrier deck

accidents is drowning. Following water impact, momentary disablement of aircrews will prevent escape from the aircraft before it sinks below crush depth. Additional impact problems for the Navy are high speed ejections and injuries occurring to the head and neck from parachute opening shock.[21]

The research of the Air Force is directed toward determining human tolerance to impact forces placed on the vertebral column, the long bones, and the joint structures of the body. These objectives are to define safety limits during high speed ejections and reduce injury.[22]

The primary objective of the Air Force research is to reduce injuries during high speed ejection from fighter/attack aircraft and multiplace bombers. Deficient low level and high level escape capability, excessive delay in initiating the decision to escape, and equipment are three factors which "account for 75 percent of the Air Force ejection fatalities."[23]

High Sustained Acceleration

Army research is not concerned with high sustained acceleration because its primary aircraft is the helicopter. The Army does focus, however, on the effects of acceleration on the visual-sensory mechanisms unique to helicopters.

The Navy's research on high sustained acceleration is concerned with the effect of high G levels on the reliability and performance of aircrews. Its purpose is to increase protection, reliability, and performance of aircrews in high performance aircraft.[24] The Navy focuses its

attention on the effects of acceleration and combined mission stress in the F-14 and YF-18 high performance fighters. The Air Force research in this area is directed toward the effects of high G levels on the organs of the body. The goal is to increase performance and protection in high performance aircraft.[25]

The maneuvering performance of high performance aircraft like the F-15, F-16, and YF-18 fighter/attack aircraft may exceed human acceleration tolerance for sustained air-to-air combat. Advances in pilot G protection and related high angle reclining seats are important in achieving maximum crew effectiveness and aircraft performance.[26]

Blast, Windblast, Downwash and Dynamic Pressure

The Army's research in blast, windblast, downwash, and dynamic pressure are concerned with defining helicopter downwash effects and blast injury to helicopter aircrews and land vehicle occupants. The Army's goal is to improve protection, crew effectiveness, decrease injury, and to enhance total mission performance.[27]

The Navy is primarily concerned with exposure to blast underwater. Its purpose is the protection from and treatment of underwater blast injury to divers and survivors of combat ship losses.[28]

The Air Force is concerned with defining the forces which cause flail injury during high speed ejection. Its objective is to reduce flail injuries and develop design

criteria for anti-flail protection.[29]

The Navy and Air Force research efforts are both concerned with reducing disabling flail injuries that occur seventy percent of the time at airspeeds above 500 knots airspeed, as well as, provide better aerodynamic design criteria for ejection seats. The Army's research is primarily concerned with minimizing helicopter downwash effects related to safety and blast injury to ground vehicle occupants.[30]

Spatial Orientation/Disorientation

In the area of spatial orientation/disorientation, Army research is devoted to determining the physiological, sensory, and environmental factors related to spatial orientation/disorientation in helicopters. Increased performance, prevention of injury and accidents, and reduction of fatigue in helicopter operations are the desired results. The Army has a joint program with the Navy in this research.[31]

The Navy efforts focus on the vestibular function and the role it plays in vertigo/spatial orientation/disorientation and motion sickness. The goal is to develop protection and countermeasures against these conditions.[32]

The Air Force directs its research toward developing visual-motor performance data. Its goals are to specify high performance aircraft control and display criteria to improve aircrew performance.[33]

Vibration

In the area of vibration, Army researchers are defining aircrew tolerance, evaluating the physiologic and hazard effects, and determining the effects imposed on the musculoskeletal system by helicopter vibration.[34]

The Navy is concerned with determining tolerance and the physiologic effects of vibration associated with high speed ships and amphibious craft.[35]

The Air Force determines aircrew tolerance to long duration vibration exposures, performance and aircraft buffet associated with high altitude, and terrain-following flight at high subsonic speeds.[36]

Noise

The Army's efforts in noise research concentrate on determining health hazards and evaluating damage risk in Army systems. The Army devotes its efforts to evaluating and developing defensive techniques against impulse noise (weapons fire) and continuous noise (communication and vehicle noise). The Army's goal is to prevent hearing loss in Army personnel and enhance mission performance.[37]

The Navy's research measures hearing loss and performance decrements in sonar exposed personnel, as well as, assesses personnel performance in naval acoustical environments. Its goal is to prevent or reduce hearing loss in Navy personnel.[38]

The Air Force is concerned with the effects of flight and ground noise on personnel safety, effectiveness, and performance. Its objective is to prevent or reduce hearing loss in Air Force personnel.[39]

Combined Stress

In the area of combined stress, the Army focuses its efforts on defining and evaluating the physiological effects of combined stressors on crew performance in helicopters and ground vehicles. The objectives are to enhance performance, prevent injury and accidents, and increase crew performance.[40]

The Navy determines operator performance and fatigue in naval aircraft and ships, with the idea of enhancing operator performance through optimal design criteria.[41]

The Air Force is concerned with the effects of long duration exposures to stress in Air Force aircraft and weapon systems. The purpose of this research is to provide better design criteria for eliminating the adverse effects of combined stress in Air Force systems.[42]

INTERDEPENDENCE/COORDINATION

As a result of diminishing resources, the laboratory commanders and representatives of the three surgeons general met on 29 January 1975 to review the aeromedical research programs of the three military departments. This meeting produced the first position paper on tri-service aeromedical research. The laboratory commanders and surgeons general

representatives acknowledged an extensive commonality of interests between the three military departments in the area of aeromedical research. As a result, they identified specific areas of lead agency and contributing agency responsibilities.[43]

Dr. Malcolm Currie, Director of Defense Research and Engineering, requested by memorandum on 7 February 1975 a tri-service effort to develop an integrated plan of research on the human effects of acceleration, vibration, and impact.[44] The tri-service plan for research on the human effects of acceleration, vibration, and impact was published 18 July 1975, and it designated primary service responsibility based on three factors: first, relevance to specific service requirements; second, capabilities and facilities of the aeromedical research laboratories; and third, technical expertise of assigned personnel.[45] This plan assigned the Army prime responsibility for developing data on prevention of crew disability in helicopter operations through improved protective systems, as well as, evaluation of aircrew performance. The Army's aeromedical research endeavors in this plan focuses on the Army's mission requirements related to helicopter air assault and medical evacuation operations.[46] The Navy's assigned responsibilities are to develop biomedical standards for head/neck/torso response, prevention of post impact disablement, and physiologically based test analogs. The Navy also develops biomedical standards for ships, motion sickness, disorientation, and combined stress in high performance

fighter/attack aircraft. The Navy's aeromedical research directly supports its mission requirement for fighter/attack aircraft and ships.[47] The Air Force was assigned primary responsibility to develop a biomedical technology data base for high performance escape systems, bone-joint-tissue strength, and air combat maneuvering capability. The aeromedical research efforts of the Air Force are directed toward the Air Force mission requirements related to high performance strategic and tactical aircraft.[48]

In addition to the 29 January 1975 position paper and the 18 July 1975 tri-service plan, a variety of mechanisms for tri-service coordination of research efforts have been established.

The first of these was established in October 1965 between the U.S. Army Aeromedical Research Unit (now Laboratory) and the Naval Aerospace Medical Institute. This agreement, entitled, "Joint Agreement on Medical Research between the U.S. Army Aeromedical Research Unit and the Naval Aerospace Medical Institute," is the basis for ongoing joint programs related to aeromedical research with particular emphasis on helicopter requirements.[49]

The second agreement was established in January 1975. It was a memorandum of understanding for tri-service coordination of aeromedical research on the effects of impact acceleration on man. A panel was chartered to identify unique and common research requirements, establish objectives, and

develop procedures for review and approval.[50]

The third agreement occurred in February 1976 between the U.S. Army Medical Research and Development Command, the U.S. Air Force Aerospace Medical Division, and the Naval Medical Research and Development Command. This tri-service agreement established a coordinating panel for all aeromedical research. The panel includes laboratory commanders, laboratory scientists, and headquarter's representatives. The responsibilities of the panel include reviewing tri-service aeromedical research, defining areas of similar need, and preparing joint research efforts.[51]

In the meantime, at the direction of the Director of Defense Research and Engineering, two major tri-service planning, review, and coordinating activities occurred. In 1971, the three military departments were asked to prepare a technology coordinating paper (TCP) on medical and biological sciences.[52] This document provided near and mid-term requirements and planned research and resource projections. The TCP was updated in 1972 and revised in 1974, 1976, and 1977.

The laboratories of the three military departments frequently participate in joint efforts with other agencies, particularly the Federal Aviation Association and the National Aeronautics and Space Administration. The laboratory scientists of the three military departments also participate actively in a number of national and international committees and professional organizations. For example, the National

Academy of Sciences National Research Council Committee on Hearing, Bioacoustics, and Biomechanics (CHABA) and the American National Standards Institutes are two national committees that provide interchange of research. At the international level, interchange of research is provided through the Working Party 61 of the Air Standardization and Coordinating Committee (ASCC) and the Advisory Group For Aerospace Research and Development (AGARD).[53]

CHAPTER III

ENDNOTES

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[3]Ibid., pp. 398-399, 413.

[4]Department of the Army, Navy, and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration and Impact, n.p. 18 July 1975. (Hereafter cited as Integrated Research Plan.)

[5]Ibid., Annex C, III.

[6]Ibid., Annex A, I-A, II-A, III-A.

[7]Ibid.

[8]Ibid., Annex C, I.

[9]Ibid., Annex A, I-B, II-B, III-B.

[10]Ibid.

[11]Ibid.

[12]Ibid., Annex C, II.

[13]Military Construction Appropriation for 1976, p. 403.

[14]Joint Chiefs of Staff, United States Military Posture for FY 1977, by George S. Brown, 20 January 1976, p. 56.

[15]Military Construction Appropriation for 1976, pp. 403-404.

[16]Ibid., p. 403.

[17]Department of Defense, Office of the Defense Director for Research and Engineering, Technology Coordinating Paper, Medicine and Biological Sciences, n.p., January 1977, pp. A-23-24. (Hereafter cited as Technology Coordinating Paper.)

[18]Integrated Research Plan, p. 3.1.6.7.

[19]Ibid., p. 3.1.6.8.

[20]Technology Coordinating Paper, p. A-24.

[21]Integrated Research Plan, pp. 3.1.6.5, 3.1.6.9.

[22]Technology Coordinating Paper, p. A-24.

[23]Integrated Research Plan, p. 3.1.6.4.

[24]Technology Coordinating Paper, pp. A-25,26.

[25]Ibid.

[26]Integrated Research Plan, pp. 3.3.6.1-2.

[27]Technology Coordinating Paper, p. A-25.

[28]Ibid.

[29]Ibid.

[30]Ibid.

[31]Ibid., p. A-26.

[32]Ibid.

[33]Ibid.

[34]Ibid., pp. A-26,27.

[35]Ibid.

[36]Ibid.

[37]Ibid., pp. A-27,28.

[38]Ibid.

[39]Ibid.

[40]Ibid., pp. A-28,29.

[41]Ibid.

[42]Ibid.

[43]Department of the Army, Navy, and Air Force, Position Paper of an AD HOC Working Group on Tri-Service Aeromedical Research, n.p., 29 January 1975, pp. 1-4.

[44]Malcolm R. Currie, "Preparation of DOD Plan for Research on the Human Effects of Acceleration, Vibration, and Impact," Memorandum, n.p., 7 February 1975.

[45]Integrated Research Plan, p. 3.0.

[46]Ibid., p. 3.3.3.

[47]Ibid., p. 3.2.2.

[48]Ibid., p. 3.2.1.

[49]Ibid., Annex A.

[50]Ibid.

[51] Ibid.

[52] Ibid.

[53] Ibid.

CHAPTER IV

EVALUATION AND COMPARATIVE ANALYSIS

THE THREAT

The major threat that the United States faces today is the Soviet Union.[1] General George S. Brown, USAF, Chairman of the Joint Chief of Staff, in his opening remarks to Congress on the defense posture of the United States for FY 1977 stated that

> . . . the ever growing military power of the Soviet Union is the most challenging military threat to our security. That power is reflected by impressive improvement in the strategic nuclear posture of the USSR vis-a-vis the United States; by the ongoing modernization of the Soviet massive land and air forces; and by the remarkable improvement of the Soviet Navy. . . . This growing military power also permits an increasingly confident Soviet Union to take advantage rapidly and decisively of targets of political-military opportunity as they develop.[2]

USSR ground forces are organized into 168 divisions, while the Warsaw Pact nations maintain approximately fifty-five divisions. In 1977, USSR and the Warsaw Pact nations maintained ninety divisions throughout Eastern Europe that were immediately available for attack on NATO forces in Europe.[3] Qualitatively, NATO tanks are superior, but they are outnumbered four to one. USSR and the Warsaw Pact nations have a quantitative and qualitative advantage in artillery.

Their large caliber weapons have greater range, as well as, outnumbering those of NATO by two to one. Their men and equipment also operate better than those of NATO in a chemical, biological, and radiological environment.[4] A comparison of the United States and USSR inventories of selected major ground weapons and equipment are shown in Table 4.

Table 4

Major Ground Weapons and Equipment
[January 1976]

	UNITED STATES	USSR
Tanks	9,000	42,000
APC and Flighting Veh	22,000	35-40,000
Artillery	6,000	15-20,000
Heavy Mortars	3,000	5-10,000
Helicopters	9,000	2,500

SOURCE: George S. Brown, United States Military Posture for FY 1977, Department of Defense, Joint Chiefs of Staff, 1976, 52, Chart 11.

The major strength of the USSR is its overwhelming superiority in numbers of major ground weapons/equipment. The one area where the United States is superior to the USSR is helicopters. A comparison of the size of the armed forces of the United States and USSR are shown in Table 5. The forces of both nations would be available with varying degrees of readiness and effectiveness at the initial stages of a major conflict. However, both nations could generate a much larger force over a longer period of time. Analysis of

Table 5

Armed Forces Personnel--January 1976
[Millions]

	UNITED STATES	USSR
Active	2.1	4.4
Reserve	1.8	6.8
Armed Militia + Other Aux Units	0	0
Total:	3.9	11.2

SOURCE: George S. Brown, United States Military Posture for FY 1977, Department of Defense, Joint Chiefs of Staff, 1976, 77, Chart 15.

Table 5 reveals USSR's superior strength in manpower.

Research and development are important factors that influence the fighting capabilities of future military forces.[5] Major research and development efforts designed to improve general purpose forces are shown in Table 6. This table is provided to show the significant research and development efforts of the United States and the USSR to improve their general force capabilities.

The collective trend of these tables reflects the emphasis of the United States and the USSR, as well as, demonstrates the growing Soviet strengths. To provide a meaningful deterrence, the United States must effectively counter the Soviet superior strength in men and weapons.

COMPARATIVE ANALYSIS

All three military departments have operational missions in which aeromedical requirements must be satisfied.

Table 6

Major Research and Development Efforts
General Purpose Forces System

UNITED STATES		USSR
	GROUND FORCES	
ARMY: AAH Helicopter		T-72 Med Tank
UTTAS Helicopter		New Fighting Vehicle
XM-1 Tank		SP Artillery(122mm, 152mm)
MICV		Tactical SAMS (SA-8)
SAMD		HIND a Helicopter
DRAGON & TOW Anti-tank Weapons		
ROLAND II		
	NAVAL FORCES	
688 Class Attack Sub		KIEV Class Carrier
LHA Amphib Assault Ship		KARA Class Cruiser
Guided Missile Frigate		KRIVAK Class Destroyer
NIMITZ Class Carrier		AMGA Class Missile Spt Ship
Guided Missile Destroyer		ROPUCHA Class List
Nuclear Guided Missile Strike Cruiser		
	TACTICAL AIR FORCES	
A-10 Close Air Spt Aircraft		SU-19 VGW Fighter/Bomber
F-15 Fighter		MIG-23 Fighter
EF-111A		SU-17/20 Fighter/Bomber
F-14 Fighter		V/STOL Fighter
F-16 Fighter		
NACF		
AWACS		

SOURCE: George S. Brown, United States Military Posture for FY 1977, Department of Defense, Joint Chiefs of Staff, 1976, 78, Chart 16.

These requirements involve ground, air, and sea combat, as well as, special roles in submarines and underwater operations. The Army's mission is oriented toward land warfare and includes developing weapon systems and equipment for a ground Army to fight, win the first battle, and control the land. To accomplish this mission, the Army depends on helicopters to compliment the ground commanders mobility, firepower, resupply, and evacuation assets.

The mission of the Air Force is oriented towards air superiority, strategic, and tactical air combat. Their aeromedical research is directed towards developing weapon systems and aircraft to enhance airpower. The Air Force uses predominately high performance, high altitude, land based aircraft to accomplish its mission. These aircraft are also designed for low level supersonic airspeeds.

The Navy's mission is sea superiority and involves developing weapon systems which compliment its successful attainment of this mission.[4] The Navy uses high speed, high performance carrier based aircraft, as well as, helicopters for protection of its sea fleet. The helicopters are used primarily in an antisubmarine role and air-sea rescue.

Aircraft resource statistics for the three military departments are shown in Table 7.

An examination of the data in Table 7 reveals that the Army is the dominant user of helicopters. Ninety-one percent of the Army's aircraft fleet are helicopters, while

Table 7

Army, Navy and Air Force
Aircraft Statistics
(FY 75)

	ARMY	NAVY	AIR FORCE	DOD
Fixed Wing Aircraft	767	4,941	10,858	16,566
Helicopters	7,968	1,306	338	9,613
TOTAL	8,735	6,247	11,198	26,179

SOURCE: Raphael I. Dinapoli, "Helicopter Aviation Medicine" U.S. Army Aviation Digest 22 (October 1976): 2.

only three percent of the Air Force aircraft fleet and twenty-six percent of the Navy's aircraft fleet are helicopters. Furthermore, the Department of Defense ratio of growth of helicopters versus fixed wing from 1960 to 1975 increased from twelve percent to thirty-seven percent, while the Army's ratio of helicopters versus fixed wing increased from fifty percent to ninety-one percent.[6]

There were 14,868 aviators on active duty in the Army in November 1975. Of this total, 14,188 or 96.6 percent of the aviators were helicopter or dual rated and 3.4 percent or 498 were fixed wing rated. Analysis of the data reveals that the ratings and numbers of Army aviators closely parallel the type and inventory of aircraft within the Army.[7]

A summary of major research facilities is provided in Tables 8, 9, and 10. An analysis of these tables reveal a commonality of equipment, as well as, requirements that exist between the three military departments. For example, in the

Table 8

Specialized Facilities
Army

FACILITY	PURPOSE	REMARKS
Helicopter Vibration Simulator	Study biodynamic problems in helicopter flight.	
Helmet Test Facility	Study head/neck injury mode. Physiologic head impact.	
Helicopter Inflight Monitoring System	Study Helicopter Aircrew performance, visual/sensory affects and effects of combined stress on helicopter aircrews.	The primary design and orientation of these facilities are directed toward evaluating aircrew biodynamic response and problem in helicopters. (See Annex A for detail.)
Helicopter Flight Simulator	Study psychological/physiological combined stress in helicopters and aircrew performance.	
Anti-Buffet and Turbulence Facility	Study cervical muscle response to symetrical/assymetrical helmet loads.	

Table 9

Specialized Facilities
Air Force

FACILITY	PURPOSE	REMARKS
USAFSAM Centrifuge Rotational Flight Simulator Small Animal Centrifuge Environmental Simulator Centrifuge.	Investigators biodynamic response to high sustained acceleration in high performance aircraft.	
Initial Accelerator Terminal Accelerator Impact Accelerator Vertical Accelerator	Investigate biodynamic response to impact forces. Emphasis is placed on whole body response.	These facilities are primarily designed to investigate biodynamic response in high performance aircraft. Studies of impact acceleration are applicable to helicopter flight.
Six Mode Vibration Facility Man Mode Vibration Facility Unholtz-Dickey Vibration Table Western Gear Shake Table Mercury Shake Table	Investigate problems in high speed flight vibrations.	

Table 10

Specialized Facilities
Navy

FACILITY	PURPOSE	REMARKS
Slow Rotation Room Coriolis Acceleration Platform Angular Rotator Human Disorientation Device	Investigate motion sickness and spatial disorientation phenomena and physiological effects of unusual vertibular stimulation.	
Horizontal Accelerator Vertical Accelerator	Study biodynamic response to impact acceleration. Research emphasis is placed on head/neck response and restraint systems.	The primary design and initial orientation of these facilities are directed toward evaluating human response and problems in high performance aircraft and specific naval problems.
Flight Simulator (Centrifuge	Investigate aircrew performance and physiologic response to high sustained acceleration. (Spin, buffet, catapult launch and carrier base operations.)	
Ejection Seat Tower	Investigate aircrew response to ejection forces.	

Table 10 (Cont)

Specialized Facilities
Navy

FACILITY	PURPOSE	REMARKS
Environmental Facilities and Hyperbaric Chambers	Investigate long term physiological effects in artificial atmospheres.	
Thermal Test Facility	Investigate protective qualities of clothing assemblies.	
Underwater Research Facility	Investigate aircrew underwater survival.	

area of high sustained acceleration both the Navy and Air Force utilize centrifuges. In the area of vibration, both the Army and the Air Force have vibration platforms. A thorough examination of the facilities, however, will show that they are designed to simulate specific aircraft or helicopters. The facilities are designed also to solve specific problem areas and to enhance specific mission requirements.

In the area of noise research, each laboratory has anechoic chambers. Vivariums, computer facilities, and optic measuring devices are also common in the laboratories. However, this is general research equipment necessary to conduct aeromedical research at any laboratory.

The research staffs have similar educational backgrounds and employ common disciplines. The scientists are trained in the life science disciplines of medicine, bioengineering, physiology, psychology, and life support, as well as, the physical science disciplines of electronic and mechanical engineering, mathematics, physics, and computer sciences.

GENERAL ENVIRONMENT IN THE ARMY

In order to meet the challenge of the USSR, the Army has increased its active divisions from thirteen and one-third to sixteen division.[8] Because of the tank threat, the Army has increased its tank killing capability by developing the armed attack helicopter and the Tubed Launched, Optically Tracked, Wire Command Linked Missile (TOW). The helicopter

recently demonstrated its flexibility and tank killing capabilities as part of the combined arms team in REFORGER 76.[9] Commenting on REFORGER 76, Major General John A. Wickham, Commander, 101st Airborne Division (Air Assault) stated:

> The helicopter must provide the ground command with mobility, firepower and logistic support in order to win the first battle of the next war.
>
> . . . The division demonstrated the combined air assault capabilities to shift troops rapidly; engage and destroy the enemy armor; provide the beans and bullets; and above all to survive in a mid-intensity environment.
>
> The division . . . generated solid evidence that the mobility, killing and staying power of the helicopter . . . and . . . [air assault division] definitely have a significant role in the defense of Europe.[10]

Through the years man has attempted to make scientific discoveries that would enhance his combat effectiveness and improve his tactical advantage.[11] This is just as true today as it was during the early years of aviation. During World War II, when military aircraft began to ascend to altitudes from 25,000 to 40,000 feet, the oxygen supply problem became acute.[12] The Germans initially sought to solve this problem by getting their fighters and bombers up and down so quickly with jet propulsion that the pilots would survive the lack of oxygen. The Germans later developed an oxygen supply system which allowed their fighters and bombers to fly over Britain at altitudes well above the tolerance of British aircrews. The allied forces worked diligently to perfect an oxygen mask and regulating system that would enable them to meet the German aircraft at their own altitude. After many

attempts, the allies successfully developed an oxygen supply system that enabled them to fight the Germans at high altitudes.[13] After shooting down 186 German planes in an air battle over Britain in a single day, someone remarked that, "the Battle of Britain was won with a few oxygen masks."[14]

The helicopter, born out of necessity to provide evacuation of casualties over the rugged terrain of Korea, is no exception to the idea of quickly adopting each new scientific discovery to gain a tactical advantage. The use of helicopters increased significantly during the Vietnam War. By the 1960s, technology had increased the helicopter's capability sufficiently to allow the ground commander a new dimension in mobility. In Vietnam, the helicopter performed effectively the functions of ground combat. It not only provided increased flexibility and firepower to the ground commander, but it performed logistic, command and control, reconnaissance, and medical evacuation functions equally well. During the closing days of the Vietnam War, a new element of firepower was added; it was the helicopter antitank guided missile system. Consequently, the helicopter brought a new awareness to Army aviation and Army aviation's ability to . . . "augment the Army's capability to conduct prompt and sustained land combat; to provide the ground commander with the mobility, firepower, and staying power needed to win the first battle; and to help the ground forces win while outnumbered."[15]

CHAPTER IV

ENDNOTES

[1]Department of Defense, Joint Chiefs of Staff, United States Military Posture for FY 1977 by George S. Brown, 20 January 1976, p. 1.

[2]Ibid.

[3]Ibid., p. 51.

[4]Ibid., p. 11.

[5]Ibid., p. 87.

[6]Raphael J. Dinapoli, "Helicopter Aviation Medicine," U.S. Army Aviation Digest 22 (October 1976); 2.

[7]Ibid.

[8]Ibid., p. 51.

[9]Reforger is an annual strategic deployment of combat, combat support, and combat service support units from the United States to Europe. The 101st Airborne Division (air assault) participated in Reforger 76. Larry J. Baughman and Robert E. Jones, Jr., "101st in Reforger 76," U.S. Army Aviation Digest 22 (December 1976); 2.

[10]John A. Wickham, "Introduction," U.S. Army Aviation Digest 22 (December 1976); 1.

[11]Detlev W. Bronk and others, Advances in Military Medicine (Boston: Little, Brown and Company, 1948), p. 207.

[12]John F. Fulton, "Medicine Warfare and History," Smithsonian Report for 1954 (Washington: Government Printing Office, 1955), p. 435.

[13] Bronk, Advances in Military Medicine, p. 215.

[14] Fulton, "Medicine, Warfare, and History," p. 436.

[15] Department of the Army, FM 90-1, Employment of Army Aviation Units in a High Threat Environment (Baltimore, MD.: U.S. Army Adjutant General Publications Center, 1976), p. 1-8.

CHAPTER V

SUMMARY/RECOMMENDATIONS

Man has sought constantly to function as well in the air as he does on the ground, but each new aerial development has created new physiological problems. The flying machines developed by man have often exceeded his physiological limits. This was true during the early developments of balloon flight, as well as, during the development of the airplane prior to and during World War II. It is also true today with the development of helicopters and modern high performance fixed wing aircraft. With the advance of technology, scientists and engineers have continuously developed aircraft which exceeded man's physiological capabilities and sometimes endangered the lives of the pilots. Each time this occurred the progress of aviation was delayed until aeromedical research could solve the problem.

From the beginning of aviation man experienced physiological problems which limited his ability to operate his aircraft safely and which limited the aircraft's performance. Man's limited ability to survive at higher altitudes was demonstrated in the first balloon flights. Paul Bert, a physician/scientist, worked in a laboratory to solve the problems encountered in high altitude balloon flight. He theorized and later proved that man's physiological problems

at higher altitude were caused by the lack of oxygen. His simple experiments to understand the biomechanics of higher altitude flight and to develop a protective system that would allow man to function at higher altitudes were the first recorded aeromedical research laboratory experiments.

The development of aeromedical research paralled the development of the airplane. The various airplane designs and their propulsion systems established the pace at which aeromedical research developed because the aircraft's design and propulsion system determined the speed, the ceiling, the vibration levels, and the duration of flight. Each new development in aircraft design brought new problems to aeromedical research.

Pre-World War I airplane development efforts concentrated on producing an airplane that would allow man to fulfill his desire to fly. Little effort or thought was given to the potential value of the airplane. Efforts were largely confined to developing airplanes that could perform better and stay aloft longer than a few minutes. When the military potential of the airplane was recognized during World War II, more complex airplanes were produced rapidly. Developmental efforts concentrated on new aircraft designs, engines, and fuels. Technological difficulties were numerous and for the most part stemmed from man's physiological requirements, i.e., the need for an adequate oxygen system at higher altitudes. The faster more complex aircraft revealed the old problem of

insufficient oxygen at altitude. Aeromedical research once again met the challenge and developed the oxygen system which has remained basically the same today.

Oxygen requirements were not the only physiological problem generated as the airplanes became faster and more complex. Visual, G tolerance to acceleration, hearing, and disorientation problems had to be solved. Each new technological development in airplanes brought new dangers and revealed new physiological limitations which aeromedical research had to consider.

After World War II, a separate Air Force was established with its own aeromedical research facilities. Consequently, the Army had few aviation assets and no aeromedical research capability. Not until the early 1960's did the Army began to rebuild its air arm. Helicopter technology had increased sufficiently to make the helicopter a practical and useful machine of war. The Army rapidly expanded its air capability using helicopters to support ground combat operations in Vietnam. Since the helicopter is an unstable platform, which flys differently than a fixed wing, new physiological problems arose. Although helicopter aircrews are subjected to those in fixed wing aircraft, the magnitude of these forces are quite different. Thus, the Army established an aeromedical research capability in 1962 to solve the physiological problems associated with helicopter flight.

The development of new helicopters with new capabilities has brought new dangers and revealed new physiological limitations of pilots. The history of aviation reveals numerous instances in which the flying machines have exceeded man's physical capabilities, and each time aviation development has had to wait on aeromedical research to solve the problems.

The greatest concentration of helicopters and helicopter pilots are in the Army. Ninety-one percent of the Army's aircraft are helicopters, while twenty-six percent of the Navy's and three percent of the Air Force's aircraft are helicopters. The Army has focused its combat support efforts on the use of helicopters, but the Navy and Air Force remains predominately a fixed wing force. The ratings and number of aviators within each military department closely parallels the type of aircraft they have. The Army has 14,868 aviators on active duty, of which 96.6 percent are helicopter or dual rated. Only 3.8 percent of the Army aviators are fixed wing rated. A viable helicopter aeromedical research capability is needed to adequately support this helicopter force.

Although the Army is the primary user of helicopters and is the single military department committed to helicopter aeromedical research, it has the smallest budget and the least capability of the three military departments. The total commitment of the Department of Defense to helicopter aeromedical research for fiscal year 1977 was less than ten

percent of the total eleven million dollar aeromedical research budget. The Navy was allocated thirty-one percent and the Air Force received fifty-nine percent of the budget. The budget programmed for helicopter aeromedical research is barely adequate to support the labor force (106 personnel) with little or no room for expansion to new programs, equipment or facilities. Inflation has further limited the efforts of the Army's aeromedical research program. The funding priorities of the Department of Defense should be reexamined with emphasis on equable funding of the three military department's aeromedical research programs.

The absence of an adequate career field for medical corps and medical service corps research scientists directly affects the retainability of professional research personnel. Furthermore, the educational facilities available to train and the number of active duty spaces allocated for training are considerably less than the Army's requirements for medical and physical scientists. Reexamination of the Army Medical Department's career opportunities in research and the numbers of spaces allocated for training is warranted.

The three military departments have recognized the need to develop a coordinated research and development plan. Formal committees have been established to eliminate unnecessary programs, prevent duplication of effort, and preserve the research efforts specific to each military department's mission. The committees provide an excellent opportunity for exchange of data and coordination of research activities.

More cooperation of this type should be encouraged.

Helicopter aeromedical research is less than fifteen years old because the helicopter was not sufficiently developed to make it a practical machine of war prior to the early 1960's. Helicopter aeromedical research is relatively young and is still in the adolescent stage when compared to the programs of the Navy and the Air Force. The Air Force has conducted aeromedical research for forty years and the Navy for approximately thirty-seven years. Their programs, capabilities, and facilities are well established to support fixed wing aeromedical research.

The Navy and Air Force places very little emphasis on helicopter aeromedical research because of their mission requirements. The mission requirements of the Air Force are oriented towards air superiority and strategic and tactical air combat. The Air Force uses high performance, high altitude, land based aircraft to accomplish its mission. This is why ninety-seven percent of the aircraft of the Air Force is fixed wing and why its aeromedical research programs are orientated toward solving those problems associated with high performance fixed wing aircraft.

The Navy's mission requirements involve controlling the seas and gaining sea superiority which require the use of predominately high performance fixed wing aircraft. Thus, seventy-four percent of its aircraft fleet is fixed wing aircraft.

The Army's mission is oriented toward land warfare and includes weapon systems and equipment for a ground Army to fight, win the first battle, and control the land. The Army is growing more dependent on helicopters to compliment the ground commanders mobility, firepower, resupply, and evacuation assets; this dependence on helicopters for the Army to accomplish its mission is an indication that more emphasis should be placed on Army aeromedical research.

An examination of the specialized facilities within the three military departments reveals major duplication of facilities between the Air Force and the Navy, particularly in the area of impact acceleration and sustained acceleration. Both the Air Force and Navy operate similar horizontal and vertical impact facilities to study the effects of impact acceleration on man. Furthermore, both of these military departments operate similar centrifuges to study the efforts of sustained acceleration on man. There is also duplication of facilities within the Air Force in the area of sustained acceleration. The Air Force operates a man-rated centrifuge at the Wright-Patterson Laboratory and at the USAFSAM laboratory. Additional study is warranted to determine the percentage of utilization of these facilities, the cost and duplication of research effort, as well as, the feasibility of combining these research activities.

The Army's specialized facilities do not duplicate those of the Navy or Air Force. Its facilities are unique

and applicable only to helicopter research. The Army's present specialized facilities are inadequate to support extensive aeromedical research in all facets of helicopter research. More investigation is needed to determine the specific areas and specialized facilities needed to adequately support the Army's expanded use of helicopters for combat purposes.

Although the Army's aeromedical research capability has grown during the past fifteen years, it remains small with inadequate facilities, personnel, and funds. This is particularly true in view of the threat the Army now faces in Europe and the Army's dependence on the use of helicopters to counter this threat. The Warsaw Pact nations presently have ninety divisions throughout Eastern Europe that are immediately available to attack NATO forces.

In major ground weapons and equipment, the USSR outnumbers the United States five to one in tanks; two to one in armored personnel carriers and fighting vehicles; and three to one in artillery and heavy mortar. Helicopters provide the only weapon system in which the United States has a superior number--four to one--over the USSR.

The major research and development efforts of the United States for its ground forces to counter the Soviet tank threat are focused on development of the Armed Attack Helicopter (AAH), Utility Tactical Transport Aircraft System (UTTAS) helicopter, the XM-1 tank and the Dragon/TOW antitank weapons. Because the United States intends to counter USSR

ground threat with tank killing helicopters and antitanks weapons, the development of helicopters is of critical importance to United States ground forces. The development of helicopters must be accompanied by sufficient helicopter aeromedical research to solve new physiological problems as they arise.

The Army has the largest investment in helicopters and helicopter aircrews of any military department. It is the only military department whose mission requirements depend on an adequate aeromedical technology base in helicopter and helicopter related weapon systems. Resources and capabilities should be increased to develop a superior technology base in helicopter aeromedical research. The increased complexity of helicopters will continue to expose man to mechanical forces such as impact acceleration forces, noise, stress, and disorientation conditions. The development of each new helicopter creates a new generation of aeromedical research problems. Among these problems are severe visual restraints, hearing difficulties, combined physiological stresses, crash survivability, and life support needs. Thus, there is a need for an aeromedical research capability immediately responsive to Army helicopter requirements.

A comprehensive reevaluation of aeromedical research priorities needs to be conducted, either within the assets of the Department of Defense and the three military departments or by contract to a civilian firm and/or educational

institution specializing in medical research management, to determine the options available for developing and expanding the technology base of helicopter aeromedical research. Specific mission areas of research with minimum funding levels should be defined, and duplication of facilities and efforts within the military departments should be better identified and eliminated. Emphasis should be placed on developing each military department's aeromedical research needs in support of its combat mission requirements; this would allow facilities and capabilities to be easily identified and supported without fear of infringement into another military department's area of responsibility.

A comprehensive evaluation could serve as a basis for realigning aeromedical research in support of specific service aircraft. In addition, such an evaluation could highlight the advantages of each aeromedical research effort and provide the Department of Defense with a more realistic picture of the actual needs and progress in all aeromedical research areas.

APPENDIX

APPENDIX A

ARMY

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

APPENDIX A

Facility: Multi-Axis Helicopter Vibration Simulator.

Description: The vibration simulator is a close loop (pilot-controlled and/or computer controlled), man-rated vibration platform specifically designed to simulate vibrations in helicopters. This facility is the first facility specially designed to evaluate physiologic, fatigue, and the hazards effects of short term and long term vibration exposures of helicopters.

HELICOPTER VIBRATION SIMULATOR

Performance Specifications	
Payload	600 lbs
Acceleration	$\pm$5G
Frequency	5-50 hz
Displacement	$\pm$4 inches double amplitude (three linear motion directions with 45° tilt and 360° of rotation).
Measurand (Wave Form)	Sine, random, triangular, complex transient.

Special Capabilities: Closed circuit TV and cine-photographic system. Physiologic/performance data acquisition system (real time). Hybrid computer. Electromyographic data system.

Test Applications:

Biodynamic problems in helicopter flight.

Weapon systems - aircrew integration.

Cockpit/instrument evaluation.

Crashworthiness studies.

Vibration effects on wounded during medical evacuation.

Facility: Helicopter In-Flight Monitoring System

Description: The helicopter in-flight monitoring system is a on-board multi-channel biomedical and flight control measurement system. This system is capable of measuring simultaneously aircrew physiological data and helicopter engine and airframe data. This system is applicable only to helicopters.

HELICOPTER IN-FLIGHT MONITORING SYSTEM

Performance Specifications
Compatibility with any helicopter airframe.
On-board measurement of critical flight control parameters.
Cockpit noise, vibration and maneuver environments.
Position tracking of flight path.
Audiovascular and visual-sensory measurement.

Special Capabilities: Photography. Computer analysis.

Test Application:

Helicopter aircrew performance.
Visual performance aids effectiveness.
Biochemical and psychosensory fatigue effects.
Helicopter combined stress effects.
Dynamic verification of helicopter aircrew integration.
Aircrew compatibility of crash protective equipment.

Facility: Helmet Test Facility.

Description: The helmet test facility is a drop tower with associated dynamic/static material test devices for biomedical evaluation of head protective equipment. This facility supports the Army's requirements in providing adequate protection in a crash environment.

HELMET TEST FACILITY

Performance Specifications
Helmet impact tower.
Standard and humanoid head forms.
Hybrid computer system.
Spectro-dynamic mechanical impedance and shock spectrum analyzer.
Real time data analysis.

Special Capabilities: Test standards meet or exceed United States and British standards for helmet test displacement/acceleration data analysis of impact and transmitted loads analysis. Harness strength and penetration resistance determinations.

Test Applications:

Physiologic head impact.
Penetration resistance.
Transmitted loads.
Head/neck injury modes.

Facility: Multi-Axis Helicopter Flight Simulator.

Description: This is a computer controlled multi-axis helicopter flight simulator which provides flight related parameters for environmental, physiological, and psychological investigation. The initial design and primary orientation of this device is to simulate flight in a UH-1 helicopter.

MULTI-AXIS HELICOPTER FLIGHT SIMULATOR

Performance Specifications
Pilot controlled only.
Degrees of Freedom - 2°.
Center of gravity shift.
Rough air turbulence.
Emergency procedures simulation.
Variable flight parameters.

Special Capabilities: Physiological and biochemical data acquisition. Real time analysis.

Test Application:

Psychological/physiological stress.
Aircrew performance evaluation.
Aircrew-helicopter instrumentation integration.
Helicopter noise effects on aircrew.
Incidence of disorientation during night vision.
Devices/helmet - head mounted sights - aircrew integration.

Facility: *Simulated Helicopter Anti-Buffet and Turbulence Facility.*

Description: This device evaluates helmet impact attenuation properties using human or animal test subjects. This special test capability simulates buffeting and turbulence conditions encountered in helicopters.

SIMULATED HELICOPTER ANTI-BUFFET AND TURBULENCE FACILITY

Performance Specifications
Industrial x-ray.
High speed photometric analysis.
Birefringent stress analysis.
Biochemical analysis.

Special Capabilities: Photography. Hybrid computer data reduction.

Test Application:

Cervical muscle response to symetrical/assymetrical helmet weight.

Paraspinal muscle response.

Multi-axis dynamic response.

Dynamics of helicopter accident victims.

Multi-axis tolerence.

APPENDIX B

U.S. AIR FORCE SCHOOL OF AEROSPACE MEDICINE

(USAFSAM)

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

APPENDIX B

Facility: U.S. Air Force School of Aerospace Medicine (USAFSAM) Human Centrifuge.

Description: The USAFSAM centrifuge is primarily designed for human and animal physiologic studies. The centrifuge has a twenty-three foot arm on which is attached a six foot two-man cockpit gondola with a spin capsule. On the opposite end of the centrifuge arm is installed a large animal platform.

USAFSAM HUMAN/ANIMAL CENTRIFUGE

Performance Specifications	
Acceleration.	20G
Rate of G onset.	3G/Sec
Payload	600 lbs
Vibration/Buffet	No
Degrees of Freedom	2 angular
Closed-loop control and display.	No

Special Capabilities: Closed circuit television. Bioinstrumentation channels (200). Anti-G facilities. On-board x-ray. Cine-photography. Invasive physiologic measures. Psychomotor performance when exposed to high gravitational. Stress imposed in the $+G_X$ direction. $+G_X$ effects on pulmonary function.

<u>Facility</u>: Small Animal Centrifuge.

<u>Description</u>: This is a small animal rated centrifuge with continuous rpm readout.

SMALL ANIMAL CENTRIFUGE

Performance Specification	
Acceleration	1-75G (100G's/46" radius)
Payload	100 lbs
Speed	0-300 rpm
Radius of Gyrations	22-46"
Centrifugal capacity	500G lbs

<u>Test Applications</u>:

Cross-correlate physiological parameters.

Validate physiological data models.

Facility: Rotational Flight Simulator.

Description: This is a 5000 lb., ten foot diameter sphere, which floats on an air bearing. The sphere provides multi-directional forces to test subjects for physiologic investigation of flight.

PERFORMANCE SPECIFICATION

Internally mounted inertia rings provide motion for the sphere in either the yaw, pitch, or roll axis. The internally mounted inertia rings are powered by hydraulic motors. Power for onboard systems include telemetry, lighting, closed circuit television, and air conditioning.

Test Applications:

Determine human tolerances to multi-directional forces.

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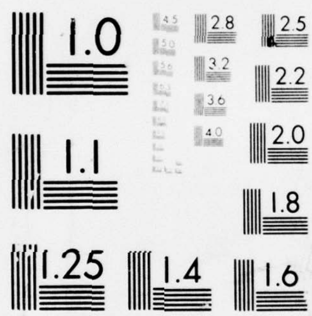

MICROCOPY RESOLUTION TEST CHART
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APPENDIX C

6570 AEROSPACE MEDICAL RESEARCH LABORATORY
(USAF)

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

APPENDIX C

Facility: Dynamic Environmental Simulator (Wright-Patterson/ Man-Rated Centrifuge).

Description: The dynamic environmental simulator is a man-rated centrifuge with a nineteen foot arm on which is located a closed loop controlled cockpit gondola. The gondola can be modified with different air force cockpit mockups to provide one-on-one closed loop simulation of air combat for measuring air combat crew performance.

ENVIRONMENTAL SIMULATOR CENTRIFUGE

Performance Specifications	
Acceleration	20G
Rate of G onset.	2G/Sec
Vibration/Buffet	0-25 hz
Degrees of Freedom	3 angular
Closed loop control and display.	Yes

Special Capabilities: Physiologic data evaluations. Closed loop(pilot controlled) target acquisition. Dedicated digital computer facilities. High performance fighter cockpit performances.

Test Applications:

One-on-one air combat simulation.
Target acquisition performance.
Aggressor-target simulation.

Facility: Vibration Facilities.

Description: The vibration facilities consist of several vibration platforms initially designed to investigate a specific problem encountered in high speed flight. The vibration facilities are designed for study of operator response to vibrations peculiar to high speed low level and high speed high level flight.

VIBRATION FACILITIES

Performance Specifications	Six Mode Platform	Mon-Mode Platform	Unholtz-Dickey Vibrator	Western Gear Table	Vertical Accelera-tion Tower	Mercury Table
Payload	2000 lbs	1000 lbs	500 lbs	500 lbs	350	500
Acceleration	±30G	±10G	±3G	±10G	±3G	±10G
Frequency	2-20 hz	20-100 hz	2-5000 hz	2-30 hz	1-10 hz	2-500 hz
Displacement	±9 to ±11" (angular/ linear)	±10" (linear)	±1.5" (linear)	±9" (linear)	±120" (linear)	±.4"
Measurand (Wave Form)	Sine, random	Sine, random	Sine, random	Sine	Sine	Sine

Special Capabilities: Computer data reduction. Photography. Physiologic performance data acquisition/reduction.

Test Applications:

Biodynamic problems in high speed flight vibrations.

Biomedical design criteria for advanced flight controls and cockpit displays.

Human tolerence studies.

Facility: Vertical Impact Facilities.

Description: The vertical impact facilities consist of a vertical decelerator, impact decelerator, and a vertical accelerator. These facilities support the air force research requirements in ejection seat technology. The primary design and orientation of these facilities are to define vetebral dynamics and the mechanical properties of joints and long bones during emergency escape involving high speed ejection from fighter/attack aircraft and multi-place escape from advanced bombers.

VERTICAL IMPACT FACILITIES

Performance Specifications	Vertical Decelerator	Impact Decelerator	Vertical Accelerator
Payload	2000 lbs	1000 lbs	225 lbs
Track length.	50 ft	35 ft	20 ft
Acceleration	75G	1000G	50G
Velocity change.	50 ft/sec	30 ft/sec	20 ft/sec
Measurand (Wave Form)	half Sine	Impulse	half Sine

Special Capabilities: Computer data reduction. Photography. Physiologic performance data acquisition/reduction.

Test Applications:

Protective restraint systems.

Crashworthiness studies.

Human tolerence studies.

Facility: Horizontal Impact Facility.

Description: The horizontal impact facility consists of an initial accelerator and a terminal decelerator. The primary design of these facilities are the simulation of dynamic forces encountered in Air Force Weapon Systems.

HORIZONTAL IMPACT FACILITY

Performance Specifications	Initial Accelerator	Terminal Decelerator
Payload	2000-10,000 lbs	2000 lbs
Track length.	200 ft.	200 ft.
Acceleration	150G	120G
Velocity change.	167 ft/sec	125 ft/sec
Measurand (Wave Form)	half Sine, triangular, trapezoidal	half Sine, triangular, rectangular complex, random

Special Capabilities: Computer data reduction. Photography. Physiologic/performance data acquisition/reduction.

Test Applications:

Biodynamic problems in high performance aircraft.

Human tolerence testing.

Crashworthiness studies.

Support/restraint systems evaluation.

APPENDIX D

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

(NAMRL)

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

Facility: Angular Motion Devices.

Description: The Navy's angular motion devices consists of a slow rotation room, coriolis acceleration platform, human disorientation device, and a periodic angular rotator. These devices provide a unique facility for investigation of motion sickness and spatial disorientation. The slow rotation room is a 500 square foot room enclosure with a 0-35 rpm controlled rotation capability. The coriolis acceleration platform is a rotating room 30 feet to 20 feet in diameter, 10 feet high on a track 40 feet long with a controlled rotation capability of 33½ rpm. The human disorientation device is a rotating cab which contains a chair with adjustable restraints which will restrain a man or animal in any position with respect to the direction of gravity or axis of rotation of the cab. The angular rotator is a angular oscillatory platform.

ANGULAR MOTION DEVICES

Performance Specifications	Slow Rotation Room	Coriolis Acceleration Platform	Human Disorientation Device	Periodic Angular Rotator
Rotational Velocity	35 rpm	33 rpm	60 rpm	100 rpm
Linear Acceleration	--	$\pm$ 3G	--	--
Degrees of Freedom	1 degree (Angular)	1 degree (Linear/angular)	2 degrees (Angular)	1 degree (Angular)

Special Capabilities: Physiological measurement. Bioelectric signals and behavioral data recordings. Human/animal subject management.

Test Applications:

Physiological effects associated with motion sickness.

Spatial disorientation phenomena.

Physiological effects of vertibular stimulation.

APPENDIX E

NAMRL - MICHOUD

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

Facility: Vibration Facilities.

Description: The vibration facilities consist of three vibration platforms. The initial design of these vibration platforms was orientated toward investigating vibration problems encountered in space flight. The Navy has redesigned the vibration platforms to support their requirements in ship motion and ship vibration research.

VIBRATION FACILITIES

Performance Specifications	C-210 System	C-125 System	MTS System
Payload	1000 lbs	1000 lbs	1000 lbs
Acceleration	80G	100G	9G
Frequency	5-2000 Hz	5-3000 Hz	0.1-250 Hz
Displacement	1 inch	1 inch	12 inches
Measurand (Wave Form)	Sine, Sinusoidal random	Sine, Sinusoidal random	Sine, Sinusoidal random

Special Capabilities: Computer Data Acquisition/Reduction Photography.

Test Applications:

Biodynamic applications of ship motion and surface effect ship vibration.

Facility: Impact Facility.

Description: The Navy's impact facility consists of a horizontal accelerator and a vertical accelerator. The horizontal accelerator is a hydraulically controlled, pneumatically driven accelerator which propels a 1,500 pound sled horizontally on a 700 foot long track. The vertical accelerator is a twenty foot vertical structure; animal rated only. The impact facility supports the Navy's research efforts in determining head-neck response to crash forces.

IMPACT FACILITY

Performance Specifications	Horizontal Accelerator	Vertical Accelerator
Payload	1500 lbs	100 lbs
Track Length	386 ft	20 ft
Acceleration	15-40 G	50 G
Velocity Change	Variable	20 ft/sec
Measurand (Wave Form)	Half-Sine, Triangular Trapezoidal	Half-Sine

Special Capabilities: Computer data acquisition/reduction, Ground and telemetry instrumentation, High speed photography.

Test Applications:

Crash simulation.
Dynamic structural testing of systems and components.
Man rated for tests involving humans.
Ejection simulation.
Impact protection.
Restraint testing.
Biodynamic applications for surface effect ships.

APPENDIX F

NAVAL AIR DEVELOPMENT CENTER
(NADC)

SOURCE: Department of the Army, Navy and Air Force, Integrated Plan for Research on the Human Effects of Acceleration, Vibration, and Impact, n.p., 18 July 1975; and Department of Army, The Surgeon General, Study of Greater Interservice Support of Aeromedical Research, Using Existing Facilities to the Extent Possible, n.p., 1 March 1976.

Facility: Dynamic Flight Simulator (Centrifuge)

Description: The Navy's dynamic flight simulator is a man-rated centrifuge with a fifty foot arm on which is located a ten foot spherical gondola. The gondola is environmentally controlled to simulate temperature extremes and vibrations of high speed aircraft.

DYNAMIC FLIGHT SIMULATOR

Performance Specifications	
Acceleration	40G
Rate of G Onset	10G/sec
Vibration/Buffet	0-25 Hz, ± 4.5 inches
Degrees of Freedom	3°
Open/Closed Loop Control and Display	Yes
Temperature	50°-90°F
Altitude	100,000 ft

Special Capabilities: Open loop; closed loop (pilot controlled); Thermal load, noise and glare; 15 Physiological monitoring parameters.

Test Applications:

Pilot controlled simulation (spin, buffet, air combat maneuvers, catapult launch, carrier base operations). Human performance and physiological responses under combined stresses (acceleration, vibration, low pressure, temperature, noise). Dynamic verification of advanced crew station designs. Dynamic testing of personal protective and life support equipment for tactical/attack carrier base aircraft.

Facility: Impact Facilities.

Description: The impact facilities consist of a vertical decelerator and a ejection seat tower. The decelerator is a 150 foot structure with a ten foot x ten foot drop seat, which freefalls to simulate the desired impact force parameter. The ejection seat tower is a 150 foot tower designed to simulate high speed ejection.

IMPACT FACILITIES

Performance Specifications	Vertical Decelerator	Ejection Seat Tower
Payload	1000 lbs	Variable
Track Length	150 ft	150 ft
Acceleration	2-2000G	30G
Velocity Change	85 ft/sec	500 6/sec
Measurand (Wave Form)	--	--

Test Applications:

Simulates dynamic ejection conditions with both live subjects, and anthropomorphic dummies.

Aircraft seat structural integrity to ejection forces.

Restraint systems.

Human response and reactions to ejection forces.

Crashworthiness studies.

Human tolerance testing.

Facility: Environmental Test Facilities.

Description: The Navy operates various environmental and hyperbaric test chambers to support underwater research requirements. These chambers vary in size due to research requirements.

Performance Specifications	9A7	Hyperbaric (High)	9A-12	Hyperbaric (Low Pressure)	Guardite
Altitude	100,000 ft	--	200,000 ft	65,000 ft	100,000 ft
Temperature	Yes	--	-80°F-+450°F	-40°F-+150°F	-65°F-+120°F
Humidity	Yes	--	5% - 90% RH at +50°F to +200°F	RH at +45°F to +120°F	5% - 95% RH at +40°F to +120°F
Man-Rated	--	Yes		Yes	Yes
Size	Two chambers w/ locks. (25' x 10' 21' x 8')	Main Chamber w/lock. (15' by 8')	Main Chamber (8'H x 10'W x 14'L)	Main Chamber (10 x 10 x 6½')	Main Chamber (6 x 4 x 3')

Test Applications:

Thermal comfort studies under different environmental conditions.
Survival equipment testing.
Hypobaric physiological and equipment testing.
Explosive decompression studies.
Long term physiological and habitability studies.
Atmosphere Studies.

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